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AN OVERVIEW OF AQUACULTURE RESEARCH IN THE SOUTHEAST FISHERIES CENTER'S GALVESTON LABORATORY[1]

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ABSTRACT

The Aquaculture Program at the Galveston Laboratory of the National Marine Fisheries Service's Southeast Fisheries Center is divided into 2 phases, experimental and demonstration. The experimental phase includes maturation and reproduction, grow-out and economical and biological evaluation. Positive economic and biological evaluation in the experimental phase will lead to phase 2, the demonstration of a pilot operation. Successful completion of the demonstration phase, which will be conducted in cooperation with industry, will eventually lead to commercial rearing of marine animals for either food, bait or seeding of wild stocks. The major thrust of this program has been to rear shrimp for bait, a research investment warranted by the demand for bait shrimp and prospects for success. Results to date indicate that shrimp can be reared in closed systems to a size suitable for sale in the northern Gulf of Mexico as bait shrimp. In addition, studies are being conducted to culture marine sea turtles, specifically loggerhead, and release the cultured juveniles into the wild in an attempt to increase wild populations of depleted, threatened or endangered species. Further, studies have been successful in rearing finfish in closed systems, and future work will be concentrated on the rearing of striped bass, redfish, and snapper for release in the marine environment as juveniles in an attempt to increase or augment wild populations.

INTRODUCTION

Federal administrators and Congressional leaders have identified aquaculture as one ocean area for major federal involvement. Congress is currently expressing its desire to fund a major thrust to develop an aquaculture industry. The Federal Government's role has been and will be to conduct and coordinate research and disseminate such information

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to industry to enhance development of commercial aquaculture. In most cases industry is unable or unwilling to mount a sufficient effort to answer all of the basic questions necessary for successful economic development of aquaculture. Our program at the Galveston Laboratory is directed to provide basic information on the culturing of semi-tropical species to achieve economic development of an aquaculture industry.

Aquaculture has advanced rapidly world-wide. Output from aquaculture has approximately doubled during the last 5 years. Aquaculture now provides 10% of world fish production. In some countries, 40% of the seafood consumed can be either directly or indirectly attributed to aquaculture (Glude, 1977). Marine aquaculture production in the United States has lagged behind the world trend with only a few examples of success. Promises of potential economic success in the United States have filled textbooks, but little actual commercial production has resulted except for oysters and salmon. However, the potential in the United States is not limited to just food production. For example, several uses of potential for economic development are: 1) develop hatcheries with the capability of producing selected fry, larvae and juveniles to replenish areas now being over-exploited; 2) provide an alternate source of bait for recreational/commercial fisheries; 3) produce high quality seafood products in areas which now rely on imports; and 4) produce a source of animals for bioassay and toxicity studies.

The goal of our program is to develop systematic procedures and define requirements needed to successfully produce and grow selected marine resources. We feel this goal can be achieved by: 1) determining the optimum level and techniques to collect live animals for spawning or grow-out studies; 2) defining maturation and reproductive characteristics, and developing supporting systems for reproduction; 3) defining conditions and developing required hatchery, nursery and grow-out systems; 4) developing and demonstrating a prototype production system; 5) determining the biological and economic feasibility of an operation system; and 6) determining and evaluating techniques and methods necessary for increasing fish, crustacean and turtle populations through seeding.

RESEARCH APPROACH

A. Program Overview

The overall approach is subdivided into 2 phases, experimental and demonstration. The experimental phase includes maturation and reproduction, grow-out, and economic and biological evaluation. Positive economic and biological evaluation in the experimental phase will lead to phase 2, the demonstration of a pilot plant operation. Successful completion of the demonstration phase, which will be conducted in cooperation with industry, will eventually lead to commercial rearing of marine animals for food, bait or seeding of wild stocks.

The basic approach to selecting a species for culture will be a screening process divided into 3 stages: 1) identify potential economic use, 2) identify biological/technical constraints; and 3) estimate the cost of culture. Selection for testing would be based on the species' high economic potential and rapid growth rate. Initial tests will be

conducted to evaluate the potential for rapid growth in an intensive culture system. Evaluation of the initial tests will determine the extent of further testing. Selection of a species for a major culturing effort will be based on such preliminary tests.

The projects within phase one are:

1. Maturation and Reproduction

a. Environmental manipulation to produce maturation and spawning. The regulation of temperature and photoperiod is a successful technique for controlling the maturation and reproduction of certain marine organisms. Specific temperature/photoperiod regimes will be utilized to induce spawning. Other factors which will be established or monitored are light intensity, water quality, tank size and diet.

b. Biochemical manipulation to produce maturation and spawning. Biochemical control of maturation and reproduction is the control of the internal metabolism of an organism. Some of the factors to be considered are hormonal effects, ovarian stimulation by eyestalk ablation and molt cycle stage determination and in vitro fertilization as they relate to the propagation of penaeid shrimp and finfish.

2. Hatchery and Nursery

Techniques for successful hatching and rearing of fish to the post-larval stage will be developed. These techniques will be based on the acceptable procedures currently used for penaeid shrimp. Experiments will be conducted to determine the environmental conditions (e.g., temperature, salinity, pH), feeding rates, stocking densities, water exchange, size and shape of tanks compatible with increased survival and growth rates of selected marine organisms.

3. Grow-out Systems

Experiments will center around the use of closed raceways for the intensive culture of shrimp and finfishes. Ponds and pens will be used as required at any point during the grow-out phase. The systems will be modified as required in response to stocking densities, flow rates, feeds and feeding rates, environmental control and waste removal procedures.

Waste removal, a key to closed intensive aquaculture, will be examined utilizing expertise developed by sewage treatment engineers and adding the concept of biological filtration with plants or animals.

4. Pathology

The health of cultivated marine organisms (turtles, finfish and shrimp) will be monitored. When diseases occur, diagnostic services will be provided and treatment and prophylactic methods recommended if these are known.

5. Physiology

Studies will be geared to evaluate the effects of environmental factors, including salinity, temperature (and their combinations), pH, density, etc., on hatching success of eggs of various fish species and the survival, growth and physiology of various larval fishes. Responses of young animals to various types and qualities of feed, both natural and prepared, will provide a guide for feeding regimes to be used in mass culture of selected species.

The projects within phase 2 are:

1. Pilot Systems

When biological methods are perfected at the research level and commercially marketable species can be reared for food, bait or seeding, a commercial pilot-scale system will be designed, built and tested. The pilot facility will be designed to handle many species and should be able to test the commercial applicability of intensive culture of both shrimp and finfish. The purpose of this demonstration program will be 1) to stimulate research and development by other institutions, agencies and private industry, and 2) to evaluate the species potential in different systems and geographical locations through cooperative efforts.

2. Evaluation

To complete the system documentation, a second biological and economic evaluation will be conducted throughout the pilot-scale investigation and decisions will be made that may cause termination or recycling to a previous activity.

B. Cooperative Research

Research and development programs concerned with aquaculture of marine organisms exist in universities, state agencies and private industry. Top priority will be given to ensure coordination and collaboration between these groups and the NMFS program to achieve maximum cooperation without duplication. This will result in the most efficient use of available funds while providing maximum progress.

The Galveston Laboratory has already entered into several cooperative agreements in order to bring better efficiency to aquaculture programs on the Texas coast. Texas A&M University and our laboratory presently share the cost of running a penaeid shrimp hatchery.

The Galveston Laboratory also collaborates with Texas Parks and Wildlife; shrimp and finfishes from NMFS hatchery programs are used to stock the grow-out ponds operated by Texas Parks and Wildlife. A new cooperative agreement is now being formulated between the Southeast Fisheries Center and Texas Parks and Wildlife which will encompass the following areas: 1) transfer of technology, 2) exchange of immature stages of finfish and crustaceans, and 3) cooperative seeding studies with the objective of enhancing wild populations.

Biologists from state agencies have been trained at the Galveston Laboratory and on numerous occasions advances in technology and equipment have been shared. The Galveston Laboratory and several private companies (e.g., Marifarms, Ralston, Weyerhaeuser, Purina, Sun Oil, Coca-Cola, and General Mills) have also exchanged information and advances in technology. Shrimp hatchery systems developed at Galveston are being used by Marifarms and the University of Arizona in Puerto Peñasco. Several Federal employees trained at Galveston have found employment in the private sector.

C. Shrimp

The Galveston Laboratory has been involved in shrimp culture research for several years and has made significant contributions to this endeavor resulting in over 30 scientific papers. The culturing techniques developed by Mock (1974) and Mock and Neal (1974) from the egg to the post-larval stage are known world-wide. In fact, the Mock technique is being used in many parts of the world today, not only in Europe, Central and South America, but Asia as well. Today the hatchery techniques for penaeid shrimp are within the state-of-the-art. The techniques for culturing algae, feeding levels and eventual production of post-larval shrimp can be obtained in a reliable manner with survival around 80%. Shrimp grow-out has been attempted by many people utilizing either intensive or extensive culture. The Galveston Laboratory has focused its attention on closed systems and intensive culturing (Neal and Mock, 1976). As a result we have developed techniques which we feel can lead to economic potential for the grow-out of bait shrimp. Mock et al. (1976) have indicated that post-larval shrimp can be reared to a size of approximately 5 g in 165 days using closed system techniques. The economic analysis of this data to date indicates that a stocking density of approximately 30/ft^2 is economicallv feasible for commercial development. We are presently attempting to determine whether this density is biologically feasible by conducting experiments at stocking densities of 30 and 50/ft^2 (Fig. 1 and 2). Preliminary results from these experiments are extremely encouraging with growth from the post-larval stage to about 70 mm in 134 days (Mock, Fontaine and Haynes, personal communication).

Our research has been centered on domestic species, namely *Penaeus aztecus* and *P. setiferus*, and we find that *P. setiferus* has a much higher rate of growth and is therefore more desirable for commercial culture. Salser et al. (1977) have indicated that other species (i.e., *P. stylirostris* and *P. vannamei*) may be more desirable than the local species found in the Gulf of Mexico. To date we have not conducted experiments with non-domestic species.

We have for several years devoted a significant effort in attempting to mature domestic shrimp species, but have not been successful. As a result, we have altered our thrust in maturation since other workers in the world such as Laubier-Bonichon (1976), Colvin (personal communication), and Lawrence (personal communication) have been successful with several other species. We are adopting these techniques to see whether or not local species such as *P. setiferus* can indeed be induced to spawn. In addition, we are attempting to obtain *P. stylirostris* and duplicate the successful system being utilized at Puerto Peñasco so that

we may use it as a control to find out whether we have a species or a systems problem with our local species. It is hoped that within 6 to 10 months we will be able to provide definitive answers on this question. This major thrust in attacking the maturation problem will be a cooperative program between the National Marine Fisheries Service, Galveston Laboratory, Texas A&M Sea Grant, the University of Houston and the University of Arizona.

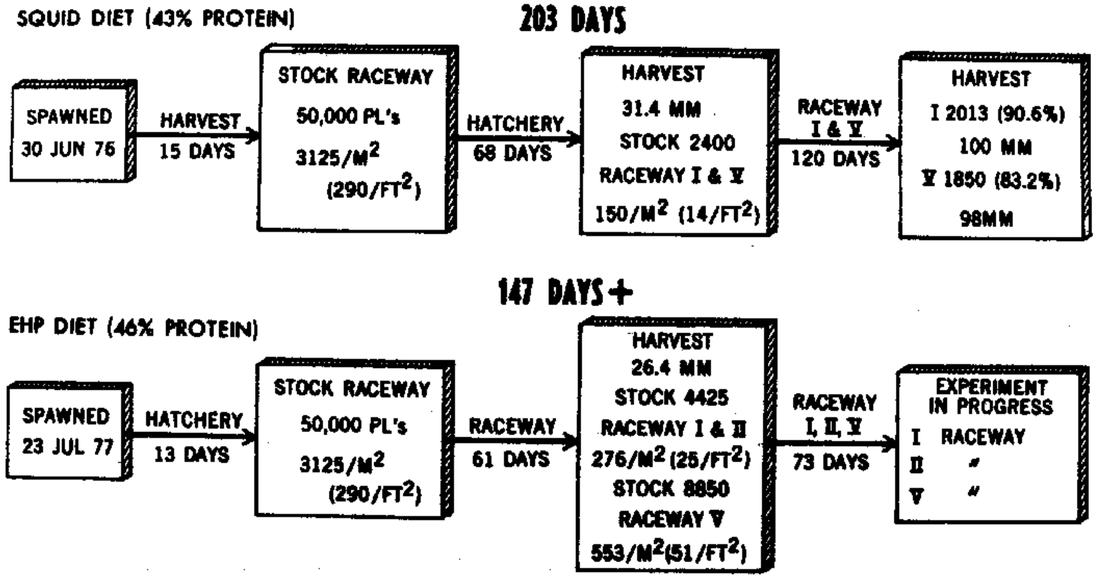

Figure 1. Summary of bait shrimp grow-out experiments.

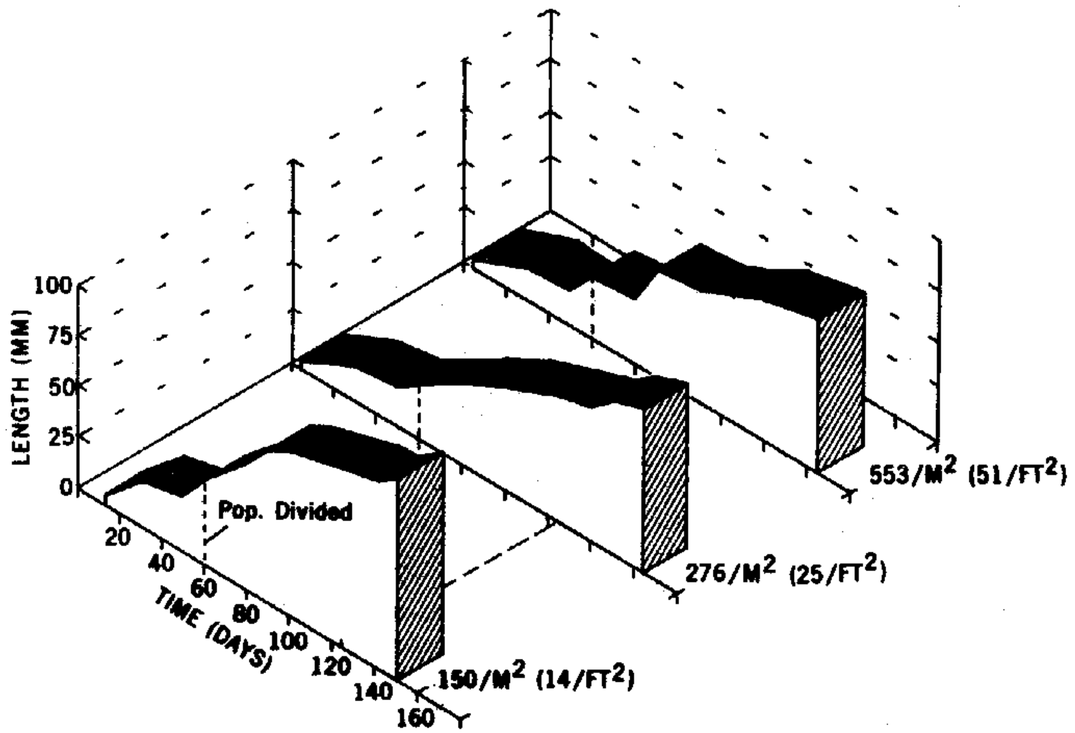

Figure 2. Summary of shrimp grow-out experiments.

D. Finfish

Prior to this time, Galveston was involved exclusively with shrimp culture, but we are now expanding to include the culture of finfish such as redfish, snapper and striped bass. We feel that these species have a high potential payload through culturing the fish to a juvenile size and the subsequent releasing to replenish wild stocks or to provide new stocks which are not presently indigenous to certain areas. We presently have a cooperative program with Texas Parks and Wildlife to capture, spawn and rear redfish. Our penaeid shrimp hatchery was modified for redfish. Redfish fry were reared to fingerling size by Texas Parks and Wildlife in their Palacious Laboratory and we are presently rearing redfish fingerlings under intensive raceway culture systems. To date these results are extremely encouraging in both rapid growth and high survival (Fig. 3). We plan to release tagged cultured redfish 6-12 in. long cooperatively with the State of Texas in the near future. We hope to expand this cooperative program by including striped bass, black drum, snapper and perhaps snook.

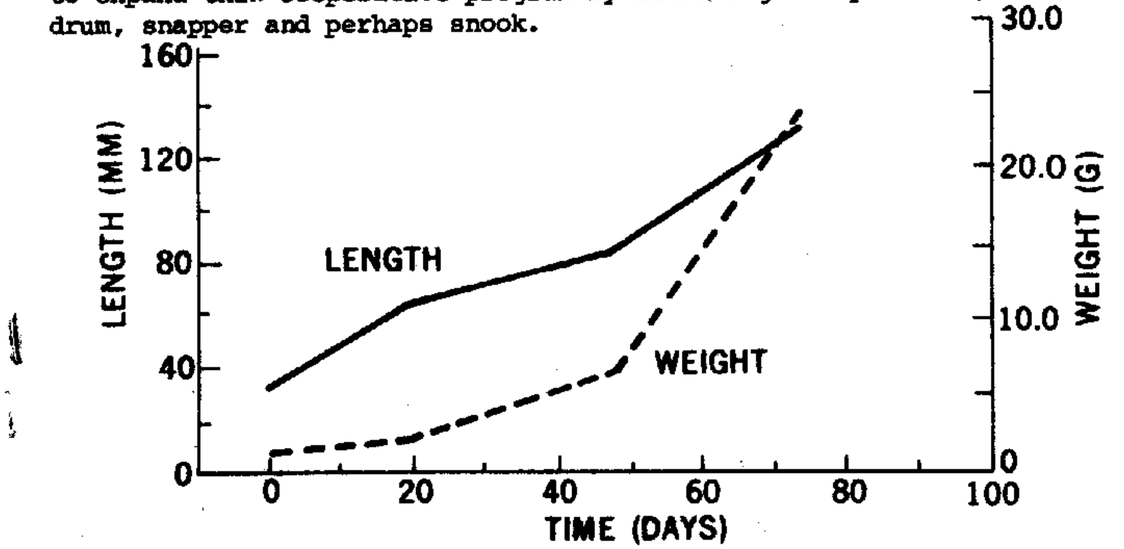

Figure 3. Growth of culture redfish.

In 1977 we conducted preliminary rearing experiments with striped bass. The rate of survival for the first 30 days was 83%; however, we had some minor problems by not providing the proper diet. We hope this year that we will be much more successful in culturing striped bass. We will attempt to release juvenile striped 6-12 in. in length in cooperation with the State of Texas in inshore areas of Texas.

E. Turtles

The Endangered Species Act (P.L. 93-205) identifies 3 species of turtles which are presently listed as endangered--hawksbill, leatherback and Atlantic Ridley. In addition, the green and loggerhead turtles have been proposed to be listed as threatened in the near future.

The Endangered Species Act limits the taking of such turtles and, in fact, prohibits the incidental taking of turtles which now occurs in the shrimp fishery industry. It is believed that in addition to

directed fishing in some parts of the Caribbean Sea, incidental taking, coupled with reduction of beach habitat for nesting turtles and man's general activity along the South Atlantic and Gulf of Mexico shoreline, has reduced turtle populations significantly in the past several decades.

The present status of knowledge concerning the life history of sea turtles is extremely limited. Most of the information about sea turtle life history has been obtained from tagging studies and observations on the nesting beaches. The nesting beaches have been determined and the internesting frequency and habitats are well known. The behavior of hatchlings is known for the first few days of their lives. At this point, the information ceases. The first year of a sea turtle's life is referred to as the "lost year" since few facts are known about it (personal communication, Dr. Archie Carr) (Fig. 4). After this time, the yearling turtles move into developmental habitats that are poorly defined. In these areas there is little information about behavior and social ecology. At some point (also unknown) the young adults move to the adult resident habitat (foraging range) where they remain until they are fully mature. It is at this time the fully matured turtle begins a series of biennial migrations to the nesting areas.

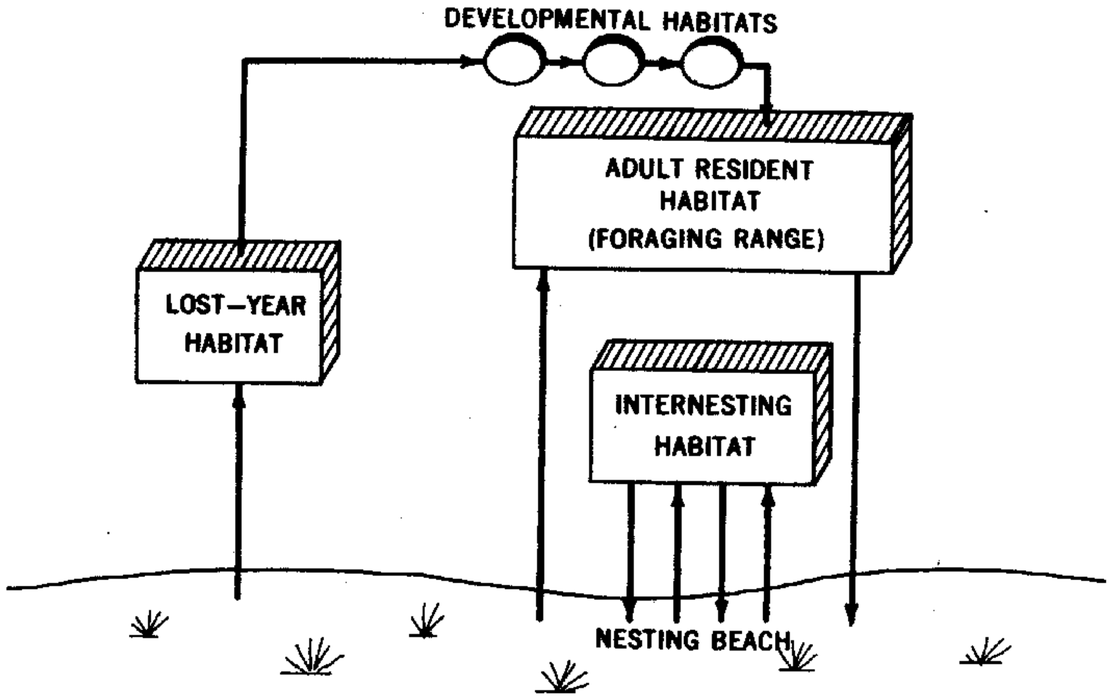

Figure 4. Model of sea turtle (personal communication, Dr. Archie Carr).

The Galveston Laboratory is now developing a "headstart" program for turtles. The technique of "headstarting," although practiced elsewhere by commercial turtle farmers and some Government conservation agencies, has never been scientifically tested to determine the degree of reliability as an accepted management technique. Questions have been raised by researchers of sea turtle biology concerning the release of

cultured turtles in the sea, such as: Do they survive after release? Do they breed and/or do they breed where they were released (success of imprinting)? What is the optimum marine habitat to release post-hatching and/or juvenile turtles?

It is evident that a long-range, scientifically designed rearing and releasing project is a necessary first step in testing the practicality of a headstart program as a viable conservation and management tool. Drs. Archie Carr, Peter Pritchard and Henry Hildebrand, authorities in sea turtle biology and conservation, have been been consulted concerning this proposal to be conducted by the Southeast Fisheries Center at the Galveston Laboratory and fully endorse this proposed activity.

Scope

This program will eventually be involved with the 3 endangered turtle species leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*) and Atlantic Ridley (*Lepidochelys kempii*), as well as the green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles. However, it was the consensus of the Galveston staff and sea turtle biologists previously mentioned to study initially with the Atlantic loggerhead for the following reasons:

1. The loggerhead is probably the least endangered species of all the species with the possible exception of the Pacific Ridley (*Lepidochelys olvacea*). Therefore, sufficient numbers of eggs and test animals should be available without posing any serious threat to the existing population, especially if they are collected from areas of heavy egg predation or loss through beach construction projects.

2. This species is most common in the southeastern United States despite a general population decline oberved over the last few decades.

3. The management techniques developed through experimentation with this species would be generally applicable to other, less abundant or truly endangered species.

4. Enhancement of the loggerhead sea turtle population in the Gulf of Mexico is desirable despite its presumed abundance in the western North Atlantic. Recent evidence suggests a substantial decline in nesting activity in the eastern Gulf of Mexico over the past decade. Loss of nesting habitat by increasing coastal development and mortalities at sea have contributed to this decline throughout its South Atlantic and Gulf of Mexico range.

The basic goal of this project will be to increase wild populations of turtles through the release of cultured animals and to obtain information on the life history of turtle stocks and provide such information to appropriate management groups. The specific objectives of this program will be 1) to determine whether released cultured animals can survive in the wild, 2) to determine whether released cultured animals breed, and 3) to determine whether released cultured animals return to specific shorelines for breeding. This program encompasses 5 major areas of investigation:

1. The collection of eggs and specimens for culturing and study: The collection of loggerhead eggs will be restricted to those areas of

beach which are presently undergoing high egg mortality and will be either in South Carolina or Florida.

2. Imprinting studies: Scientifically evaluate what mechanisms could imprint turtles to specific shoreline areas for nesting. A major goal will be to repopulate depleted nesting beaches in the Southeast United States. However, to insure optimum nesting survival of species now being decimated on present nesting beaches, imprinting to protected and inaccessible (to man) new beaches will be investigated.

3. Rearing of marine turtles for seeding: The Galveston Laboratory presently has capabilities for rearing of shrimp and finfish and some of these facilities can be used for the rearing of marine sea turtles. The raceways and sewage treatment capabilities appear ideal for turtle culture.

4. Release and monitoring of hatchlings, juveniles and sub-adult turtles: Cultured animals would be tagged and released into the wild at times and places which coincide with their normal biological cycle or areas deemed convenient but not necessarily appropriate because of management constraints. The release of hatchlings, juveniles and sub-adults will be monitored through radio tracking or sonic tags to determine migration patterns and evaluate behavioral characteristics. Before release, models of drift patterns in the target release area will be developed to predict possible migration routes. Radio transmitters attached to the turtles will be used to monitor behavior and migration routes. Radio drogue buoys would be used to verify current pattern in the release area. Using these data, models would be developed to predict the location of turtles during various phases of their life cycle.

5. Tags and tracking technology: A portion of the program would be devoted to evaluating and testing tags on hatchlings and to developing remote sensing techniques to monitor juveniles and sub-adults on a continuous basis. This phase of the program is relatively important since no information is available on the location of juvenile, sub-adult, and adult turtles during certain phases of their life cycle. The monitoring of released juveniles and sub-adults will be essential to evaluate the effectiveness of releasing various ages and numbers of turtles as well as evaluating the potential for increasing turtle stocks through seeding.

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